Designing and Tracking Play Styles in *Solving the Incognitum*

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Abstract: An acute understanding of how learners behave within educational games is crucial to building personalized learning games. Although most traditional instruments are designed to measure one's intrinsic characteristic such as motivation, they may not indicate how the learner will play a specific game. In this paper, we present a study in which we use a combination of traditional instrument and gameplay data to track how learners behave in a small-scale learning game called *Solving the Incognitum.* Our main contribution is that this study is among the first to provide empirical evidence that learners change their play styles within the same gameplay session.

Introduction

Better understanding of players' motivation and their gameplay patterns is crucial to build educational games that can be adapted to an individual learner's needs and preferences. For example, by monitoring a learner's progress in her gameplay, we may make inferences on her current motivations and dynamically adjust the game accordingly in order to improve her experience (Zhu et al., 2014).

In this paper, we present our findings about how players adopt different play styles in *Solving the Incognitum*, a game-based learning environment designed to support learners with different goal achievement orientations and play styles. Our particular focus is on the Achievement Goal Theory (AGT) (Elliot & McGregor, 2001) from motivation research and an AGT-based framework on player types (Foster, 2009; 2011). In our recent exploratory study with college freshmen (75 participants), we collected data on the participants' goal achievement orientation through a series of surveys and we collected play style information from screen recordings and game telemetry data while they played the game. We study the relationship between the identified player types, the observed play style, and, the learning outcome after playing *Solving the Incognitum*.

We present our preliminary findings that, the identified player types and the observed play style did not have a significant impact on learning outcome even though all the participants demonstrated a knowledge increase between the pre and post tests. Moreover, in our exploratory study we did not find a relationship between the identified player types from our surveys and the observed play style. We also present that, based on analysis of screen recordings, most participants in our exploratory study adopted different play styles as they went through the game.

Theoretical Framework

Player types are defined by individual traits or underlying motivations of a player (Heeter, 2009). Although they cannot be observed directly, it has been suggested that one way to construct a player type is through the combination of observable player behavior and the motivations that drives her.

Motivation research has shown that there are generally two types of orientations for learning — performance and mastery (Ames, 1992; Grant & Dweck, 2003). Students with performance goal orientation focus on external goals such as scores and grades to validate their success. By contrast, students with mastery goal orientation achieve a sense of satisfaction from the detailed understanding of the work and are not influenced by extrinsic factors such as scores or grades (Riedl et. al., 2008). Finally, there are students who avoid mastery, but are not performance oriented. Based on mastery and performance orientations from Achievement Goal Theory (AGT) (Elliot & McGregor, 2001; Heeter et al., 2011), we uses Foster's framework (2009; 2011) which proposes general categories of player types. First is *Explorers,* who explore their personal preferences and explore parts of the game that may not be necessary to advance. Second is *Goal-Seekers,* who focus on finding the fastest ways to completing the game. This means that Explorers are inclined to experience a wider range of in-game content while Goal-Seekers tend to focus on the content necessary for winning.

By contrast, play style is the "*actual play behavior enacted while playing a specific game*" (Magerko, 2010, p. 263). As play style is directly tied to players' observable in-game behaviors, it is relatively straightforward to measure. However, according to previous studies using self-reported data, a player may adopt different play styles in the same game, for instance, based on how confident he or she is about achieving her goals at a given moment, either between a play session to another or within a single play session (Foster, 2009; 2011; Heeter, 2009, Klug & Schell, 2006). Beyond player choices, the design of games themselves limits available options to players: control and expression in games are confined by their genre and their underlying design patterns and thus can only support a certain set of actions and strategies. Such limitations by game design decisions therefore constrain the possible play styles a player may engage in (Foster, 2009). Compared to existing work, the main contribution of this paper is to study play styles based on both self-reported data and observation of how learners interact with the game.

Designing for Play Styles

Solving the Incognitum is a first-person point-and-click 3D interactive learning environment for teaching the relationships between geological time and fossil records. In an environment based on the Charles W. Peale's Museum of Art and Science, the largest natural history museum in the U.S. in the early 19th Century, the player can interact with museum exhibits including fossils, minerals, strata deposits, and portraits of renowned historical figures related to the exhibits (Figure 1). By correctly answering questions related to these exhibits, the player can eventually assemble the crown jewel of the historical museum — the skeleton of the mastodon exhumed by a scientific team led by Peale in 1801. Overall, the educational goal of the game is to teach concepts related to 1) Law of Superposition, 2) Geological Time, and 3) Mastodon Life. After a brief tutorial, the player can explore the virtual space, examine different exhibits and answer questions about them.

Figure 1: The virtual environment is modeled after Charles W. Peale's Museum.

In order to support the different play styles a player may adopt, the game is designed to provide different gameplay options. For goal seekers, whose main objective is to win the game, *Solving the Incognitum* provides a clear goal. In order to unlock the assembly of the mastodon skeleton, the player needs to complete four main quests. Each quest requires the player to visit several exhibits, read the information cards associated with them, and apply the knowledge they learn to answer related questions. Once the full skeleton is assembled, the player is given the option to quit or continue the game.

For explorers, the environment contains different types of exhibits grouped based on their types and associations to one another. The player can explore them based on her own interest and answer questions about certain exhibits. Although they do not contribute to the unveiling of the missing mastodon skeleton bones, visiting these optional exhibits can earn the player badges (e.g., Junior Science Historian, Master Mineralogist, Junior Paleozoic Explorer, etc.) once the player has visited certain percentage of exhibits from each category.

The location of the exhibits in the virtual museum is determined based on their type (e.g., fossils) and the geological time period they are from. This spatial organization is designed to potentially catch the differences between play styles. While an explorer may spend time in the same location to interact with certain type of exhibits or time period of her interest, a goal-seeker is more likely to move from one place to another collecting only the necessary exhibits to win the game.

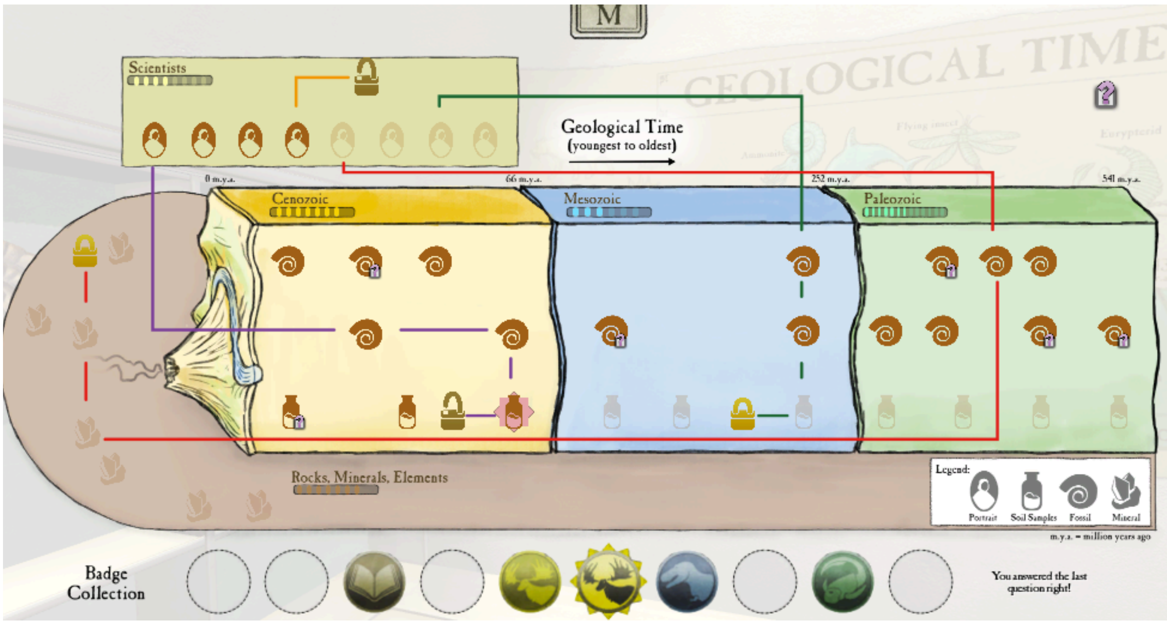

Figure 2: Concept map that helps the student track the exhibits they visited and the relationships between them.

To provide an overview of all the exhibits as well as the winning path, *Solving the Incognitum* has a *concept map* that the player can open at any time (Figure 2). On the map, all exhibits required on the four main quests to unlock the skeleton are visibly connected through solid lines. When an exhibit has been visited, it turns from transparent to full color on the map. To avoid clutter and to improve gameplay recording, the name of an exhibit will only appear when the player moves the mouse over its icon. The concept map also shows the percentage of visited exhibits in each time period and category, and the earned badges.

Methods

To study the relationships between player types and play style and how they affect learning in *Solving the Incognitum*, we conducted an exploratory study with college freshmen majoring in Digital Media in a required class. Our study group consisted of 75 students who volunteered to participate.

We asked each participant to first complete a 12-question pre-knowledge test about the basic earth science topics covered in the game before they played the game individually. During their gameplay, we recorded their screens and the game automatically recorded all their gameplay data. The participants were given the instruction to play the game for up to 60 minutes, though they were not told to complete the game. When they finished playing the game, the participants were asked to complete a post-knowledge acquisition questionnaire, a 15-question AGT survey (Elliot & McGregor, 2001) and an 11-question player type survey (Foster, 2011). We used Cronbach's alpha to ensure internal reliability in the survey questions. Cronbach's alphas for the 3 performance avoidance, 3 performance approach, 3 mastery approach, 6 mastery avoidance, 3 localized explorer, 4 comprehensive explorer, 2 achievement goal-seeker and 4 competitive goal-seeker items were .812,

.896, .879, .884, .867, .751, .868 and .823 respectively. To avoid bias in the knowledge acquisition questionnaires towards either play style, the questionnaires address all of the game's learning goals and include topics covered in both goal-related and optional exhibits. Regarding the survey, we used reliability constructs to check for internal consistency of the questions. Since the game is single-player, we only focus on the main player types of goal-seeker and explorer, without considering the social aspects that will further divide these into subcategories of the major types. In order to assign a single category label to each of the participants, the aggregated values for each of the 2 types are compared and the larger of the two is assigned as the participant's type.

After the study, two researchers independently coded the screen recordings of all participants to identify their play style. The set of guidelines used for annotation was developed from pilot gameplay data and used for training to ensure internal consistency and validity. As we observed significant shifts of play styles in many players, we segmented the video based on the four main quests. For each segment, the coders manually annotated the video with a binary label (explorer or goal-seeker) along with 3 additional attributes: confusion, interest and the annotator's confidence.

The coders looked for activities and behaviors regarding navigation, use of the concept map, items visited and order of actions completed. For goal-seekers, a strategy for completing the objectives was examined, as well as how the participants developed that strategy. The two strategies for completing the quests in the minimum amount of time consist in using the concept map for locating the exhibits that unlock the mastodon skeleton bones and then either locating the required items in the concept map itself or going to the unlocking exhibit and getting the list of required exhibits from there. For explorers, the main indicator is the lack of such a strategy and instead how the participants interacted with different items based on their own interests. A 3-point confusion scale was assigned to capture whether a participant appeared to understand how to navigate the environment, the goals or the usage of the concept map; or appeared to wander around without interacting with the exhibits. An additional 3-point interest scale was added to annotate participants who did not appear to be interested in the game — they did not read the material on the info cards or did not make an effort to answer the questions. When the two coders agreed that a player was confused over a predefined threshold (mean > 2.0) or interested below a predefined threshold (mean < 2.0), the observed play style label (explorer or goal-seeker) is replaced with either *confused* or *uninterested*.

Results

In this section we present our findings on the study of the relationships between player types and play style and how they affect learning in Solving the Incognitum. Note that from the data collected on the 75 participants, we discarded 17 data points due to missing instruments (video recording, gameplay data, survey or questionnaires).

Learning Outcome for Survey-Based Play Styles

Based on the surveys (AGT and play style), there were 30 goal-seekers (51.72%) and 20 explorers (34.48%). We will refer to them as *survey-based* (SB) player types to distinguish from the play styles we observed based in gameplay. In addition, 8 participants (13.78%) were unidentifiable as they had an even balance between the two play styles and our survey analysis did not target the approach-avoidance dimension in AGT.

The mean scores for pre-knowledge test and post-knowledge tests for all of the participants were 2.081 and 5.571 respectively out of 12 points, one point for each question in the knowledge tests.
A paired sample t-test was used to measure the significance of the difference between pre-knowledge test and post-knowledge test scores within the different subgroups. When testing for significance, for all participants as well as for each subgroup of participants, the increase in the post-test was statistically significant, indicating that the game had a positive effect as a learning tool. Table 1 reports the mean and standard deviation of the tests and the effect size for each group and subgroups of motivation approaches. Explorers (SB) had the largest effect size found from the t-tests between the knowledge test scores at 1.682 standard deviations while goal-seekers had a lower effect size of 1.598 standard deviations. Explorers (SB) also had higher pre-knowledge and post-knowledge test averages.

	Pre-Test		Post-Test			Mean Difference**			
	Mean	Std.	Mean	Std.	n	Lower	Upper	p	d
All Participants	2.081	1.304	5.571	2.166	58	2.935	4.046	0.000*	1.652
Goal-seeker	1.903	1.339	5.283	2.075	30	2.590	4.170	0.000*	1.598
Explorer	2.630	1.173	6.007	2.213	20	2.437	4.316	0.000*	1.682
Unidentifiable	1.375	1.061	5.562	2.485	8	2.104	6.271	0.002*	1.680
**two tailed t-test with p<.05* ** 95% confidence interval									

Table 1: Summary of test scores, number of participants and effect size for the different groups identified from the AGT + player type survey (n=58).

Learning Outcome for Observed Play Styles

The 58 gameplay sessions range from 9 to 54 minutes of gameplay (mean=21.42 minutes, std=8.01 minutes). An automated logging system in the game recorded an average of 4,558 events such as mouse clicks, key presses or exhibit interactions (std=1,270). Based on our annotation, there were a total of 24 observed Goal-Seeker (41.37%), 15 Explorer (25.86%), 10 uninterested players (17.24%), 5 confused players (8.62%), and 4 couldn't be assigned either label (6.89%).

The pre-knowledge test and post-knowledge test score means for observed explorer tendencies were 1.693 and 6.060 respectively, for observed goal-seekers they were 2.556 and 5.762, for confused players the means were 1.200 and 3.747 and for players who did not care or show interest in the content the means were 1.797 and 4.807. The detailed comparison is reported in Table 2 along with a comparison between overall observed tendency, constant tendencies and participants shifting between tendencies (described in the next section). The observed tendencies reported in this section represent an overall tendency for each participant as agreed by the annotators. A paired sample T-test used to measure the significance of the difference between pre and post knowledge test scores showed that the means for each group were significant with p values less than p=0.05 with the exception of the confused players, whose p value was p=0.125. There was no relationship found between the observed data and the results from the motivation and player style survey.

	Pre-Test		Post-Test			Mean Difference**			
	Mean	Std.	Mean	Std.	n	Lower	Upper	p	d
Explorer	1.693	1.185	6.060	1.909	15	3.324	5.503	.000*	2.243
Goal-seeker	2.556	1.269	5.762	1.963	24	2.379	4.035	.000*	1.636
Uninterested	1.797	1.128	4.807	1.771	10	1.625	4.395	.001*	1.555
Confused	1.200	1.095	3.747	3.453	5	-1.101	6.194	0.125	0.867
Other	2.500	1.915	6.783	2.521	4	0.609	7.958	0.035	2.048
Constant Explorer	1.750	1.173	6.350	1.412	6	2.765	6.435	.001*	2.631
Constant Goal-s.	2.588	1.353	5.596	2.083	8	1.019	4.998	.009*	1.264
Non-Constant	2.034	1.316	5.461	2.277	44	2.787	4.066	.000*	1.630
**two tailed t-test with p<.05* ** 95% confidence interval									

Table 2: Summary of test scores, number of participants and effect size for the different groups identified from the annotated observations (n=58).

Furthermore the individual question responses in the player type survey and in the pre- and post-knowledge test questionnaires were studied using Pearson correlation against the observed play style labels. The survey intends to cover the AGT player types and we expected it to have a high degree of correlation with the observed overall play style tendency for each participant and should allow us to use linear regression to predict a participant's play style given their player type survey responses. The aggregated Likert responses related to the explorer and goal-seeker player types (SB) exhibit a correlation of 0.119 and 0.059 respectively to the explorer and goal-seeker observed play styles, which we could not effectively use for prediction. The best performing questions from the player type survey in terms of positive correlation, with this regard are: "*I am striving to avoid performing worse than others in this science game*". (0.214) and: "*I prefer exploring the game world over completing* *particular objectives".* (0.166). Since the annotations also include extra labels for confused and uninterested participants, those two were considered as disjoint categories and the previous data studied using Pearson correlation. Counterintuitively, we found a correlation lower than expected between the knowledge gain and the observed participants labeled as confused and uninterested (0.088). On the other hand, some questions regarding typical gaming play style showed correlation with the participants observed as uninterested. The questions are: "*Finding and using gaming strategies is very important to me".* (0.419) and: "*I prefer exploring the game world over completing particular objectives."* (0.169).

Shifting Play Styles

Our data confirms existing theories (Foster, 2009; 2011; Heeter, 2009, Klug & Schell, 2006) that a player does not always stay with the same play style during the same gameplay session in a fixed context. Compared to existing work, our study is among the first to provide gameplay data and illustrate *how* players switch between different play styles.

As we observed what play style the participants adopted during their entire gameplay session, only 14 people (24.13%) exhibited a consistent play style. 8 of them adopted the goal-seeker play style and 6 explorer play style. When we classified their behavior at the granularity of a quest, the rest of the participants all made at least one shift.

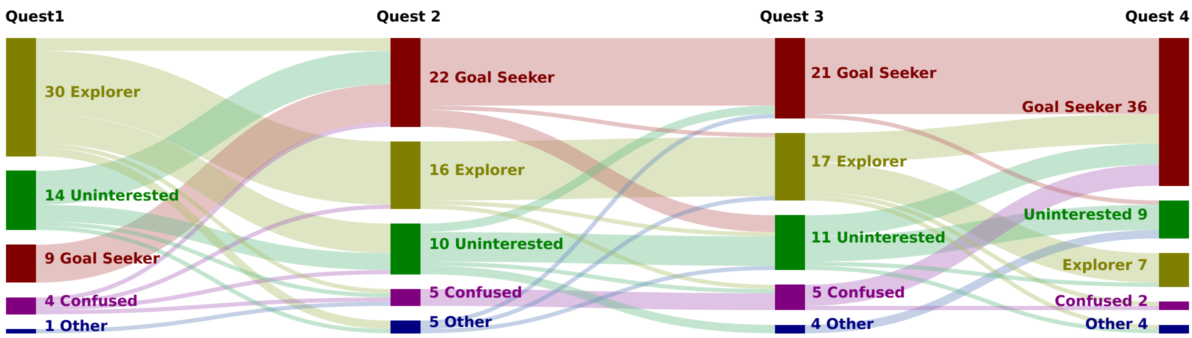

Figure 3: Alluvial diagram of how participants (n=58) shift their observed play styles between the four quests in the game.

Figure 3 is an alluvial diagram that shows how participants shift their observed play styles between the four quests. Each vertical block represents one of the four main quests. Each block is divided into the 5 observed play styles based on how many participants were observed to adopt that play style for a given quest. The stream fields between the blocks represent changes in the composition of the play style clusters over time. For instance, the amount of observed explorers is 30 (51.72%) in Quest 1 while the number dropped to 7 (12.07%) by Quest 4. Figure 3 shows the trend of how participants move between the styles. For example, all 9 observed goal seekers in Quest 1 continued as so in Quest 2, while 13 other participants previously identified as explorer and uninterested also adopted this play style for this quest.

Analyzing their learning outcome, we found that players that were observed to maintain a consistent explorer play style showed better performance in the post-knowledge test and an overall increase in knowledge gain compared to the rest of the players, either switching or not. The bottom rows in Table 2 summarize the results for participants with an observed constant play-style and participants who shifted between play styles.

Discussions

Our work differs from previous related research in which we use empirical data instead of self-reported data to support our results. Our major finding is that players switch their play style through a single game session in a manner that is not consistent with their identified player type from self-reported data. We attribute the substantial divergence between the player types identified in the survey and the observed play styles to the broad scope of the responses from the survey (general gaming interests and study preferences) versus the constrained nature of the learning environment we asked the participants to play.

Our analysis provides arguments to question the validity of using player types identified from survey and questionnaire results for the study of a particular game or interactive learning environment. Instead, our results indicate a weak relationship between identified player type and observed play style and show how players switch from different play styles over the course of a play session. We conducted a user study with 75 participants from which we collected 58 play session data. We observed how initially participants exhibited an explorer play style but many switched to goal-seeker play-style through the play session. We also observed many reluctant players who showed little interest in the pedagogical content presented by the learning environment. Our observations are supported by evidence gathered from the recorded gameplay data from our user study and are aligned with previous research but caution must be taken in drawing generalized conclusions as the design of the virtual environment may have a direct impact on play style.

Conclusion and Future Work

In this paper we presented the game mechanics of *Solving the Incognitum*, designed to allow learners of different player types to engage in different gameplay activities. Based on our study, *Solving the Incognitum* was able to increase the participants' knowledge of the earth science concepts in the game, although we did not find strong correlations between learning outcome and specific player types or play style. Our data shows that the majority of our participants switched their play styles, many did so more than once, in their gameplay and we presented how and when they switched. We believe this is still an early exploratory study but raises interesting issues for future studies.

Our findings confirmed the need for tracking learners' play styles and motivation in real time. In our future work, we plan to further analyze our recorded gameplay data and develop a player model that can recognize a player's style and potentially motivation.

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